APPLICATION FOR UNITED STATES PATENT

Inventor(s): Shimon Eckhouse and Michael Kreindel

Invention: METHOD AND APPARATUS FOR SKIN REJUVENATION AND WRINKLE SMOOTHING

FOLEY & LARDNER
777 East Wisconsin Avenue
Milwaukee, Wisconsin 53202

Attorneys

Telephone: (414) 271-2400

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SPECIFICATION

METHOD AND APPARATUS FOR SKIN
REJUVENATION AND WRINKLE SMOOTHING

FIELD OF THE INVENTION

The present invention relates generally to the art of skin treatment using electromagnetic radiation. More particularly, the invention relates to an efficient method and apparatus for skin rejuvenation by ablation of the outer layer of the skin and wrinkle smoothing (or shrinking) by heating of collagen without damage to the epidermis.

BACKGROUND OF THE INVENTION

There is a strong desire today to obtain and/or maintain a youthful appearance. One manner of doing so is to remove (or reduce) wrinkles. Additionally it is desirable to rejuvenate the skin by removing an outer layer of skin. There are known techniques for removing wrinkles by peeling the skin. Also, there are known methods for rejuvenating the skin. Unfortunately, all known techniques suffer from lack of efficacy and risk to the patient.

One known method of skin rejuvenation includes injection of collagen underneath the skin. This has been performed using a bovine collagen injection. For example, microfine collagen has been injected into periocular lines. Some of the problems with collagen injection include, allergy to collagen and lack of longevity. Also, often there is only partial eradication of the wrinkles.

Peeling most or all of the outer layer of the skin is another known method of rejuvenating the skin. Peeling can be achieved chemically, mechanically or photothermally. Chemical peeling is often carried out using trichloroacetic acid and phenol. An inability to control the depth of the peeling, possible pigmentary change and risk of scarring are among the problems associated with chemical peeling.

The mechanical method is called transcutaneous blepharoplasty and involves shaving off the outer layer of skin. Skin resection during lower lid blepharoplasty frequently results in undesirable side effects, especially ectropion and scleral show. Moreover, transcutaneous blepharoplasty rarely eradicates all of the wrinkle lines.

Pulsed carbon dioxide laser treatment is a known photothermal method of removing of periocular wrinkles. However, laser light is heavily absorbed in water and has a very short range in the epidermis. Thus, a high fluence with short pulse durations will evaporate the outer layer of the skin and peels most or all of the epidermis.

The use of CO_2 laser light for skin rejuvenation also has undesirable side effects. For example, CO_2 lasers have small spot size (3mm or less), and thus their use causes valleys and ridges, particularly when resurfacing large areas. Also, it is difficult to control heat diffusion, and thus the resultant necrosis is difficult to

predict and control. Additionally, scar tissue absorbs CO_2 laser light differently than normal skin and thus may adversely impact such a treatment.

Thus, it is apparent there is a need for a new method and device with which it is possible to produce efficient wrinkle removal and skin rejuvenation. This apparatus would preferably be able to control the treatment parameters according to characteristics of the tissue, and be easily tunable. The new method and device would preferably provide efficient wrinkle smoothing and skin rejuvenation with minimal side effects.

SUMMARY OF THE PRESENT INVENTION

In accordance with one aspect of the invention a method and apparatus for treating skin includes applying pulsed light to the skin to heat and shrinking collagen within the skin, thereby reviving the elasticity of the collagen and of the skin. In one embodiment the method also includes protecting the epidermis and outer layers of the skin by cooling the epidermis and outer layers of the skin. The cooling may be accomplished by applying a cooled transparent substance, such as ice or gel, to the skin.

In one alternative embodiment the skin is cooled by applying the transparent substance to the skin and then cooling it.

In another alternative embodiment the temperature distribution within the skin is controlled by controlling the delay between the time the coolant is applied, and the time the light is applied. A microprocessor may be used for determining the delay time in response to a selected skin temperature profile. Additionally, the temperature distribution may be controlled by controlling the pulse

duration and applying multiple pulses. In another embodiment the temperature distribution within the skin is controlled by filtering the light and controlling the radiation spectrum. Preferably, the spectrum includes light having a wavelength in the range of 600-1200nm.

In another embodiment the pulsed light may be incoherent, such as that produced by a flashlamp, or coherent, such as that produced by an Nd~~(Yag)~~:YAG laser or a ruby laser.

In another embodiment the light is directed to the skin using a flexible or rigid light guide.

In accordance with a second aspect of the invention a method and apparatus for generating a temperature distribution inside a region of skin having a maximum temperature at a selected depth includes cooling the epidermis and outer layers of the skin and applying pulsed light to the skin.

In one embodiment the cooling is accomplished by applying a cooled transparent substance, such as gel or ice, to the skin. Alternatively, the cooling may be accomplished by applying the transparent substance, and then cooling it.

The temperature distribution is further controlled in one embodiment by controlling the delay between the cooling and the light application. In another embodiment the distribution is controlled by controlling the pulse duration and/or applying multiple pulses.

In accordance with a third aspect of the invention a method and apparatus for cutaneous resurfacing includes directing Er:YAG laser light to the skin. The light may be pulsed, preferably with a delay of about 0.5-10msec between pulses. In one embodiment the pulses have energy fluences of preferably about 100J/cm^2.

In accordance with a fourth aspect of the invention an apparatus for the cutaneous resurfacing of a region of skin, including skin resurfacing or wrinkle smoothing, includes an incoherent light source such as a flashlamp and an Er:YAG laser. The laser can be operated in a multiple pulse mode. A delivery system delivers the incoherent light and laser light to the region to be treated, and the region may be cooled.

Other principal features and advantages of the invention will become apparent to those skilled in the art upon review of the following drawings, the detailed description and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a temperature distribution achieved inside the skin after a cold fluid was applied to the skin, for a plurality of different time delays after the application of the cold gel;

Figure 2 shows a temperature distribution achieved by precooling the skin and applying the light source;

Figure 3 is a schematic illustration of the flashlamp light source according to one preferred embodiment of the present invention; and

Figure 4 shows a normalized output filtered radiation spectrum of a flashlamp light source.

Before explaining at least one embodiment of the invention in detail it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments or being practiced or carried out in various ways. Also, it is

to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention relates to a new method and apparatus of removing wrinkle and rejuvenating skin. Generally, in accordance with this invention, wrinkles are smoothed or reduced by collagen molecules shrinking and increasing the elasticity of the skin and collagen, using a short heating impulse (thermal shock). Tissue is heated at a depth of up to a few millimeters by light radiation, while the skin is externally cooled at the surface to avoid overheating the epidermis. The epidermis may be cooled in a variety of ways, including applying a precooled (i.e., a temperature less than the ambient temperature) transparent substance such as ice or cold gel to the skin. The cold substance should cool the skin before and during treatment. The light (electromagnetic radiation) is applied to the skin in pulses shortly after the application of the cooling material. Alternatively, the fluid or gel could be applied to the skin or skin surface, and then cooled (using thermoelectric cooler, e.g.) shortly before the application of the pulsed light to the skin.

The light source will preferably provide a spectrum such that the optical depth of penetration into the tissue is of the order of 1mm or more. Also, the light source will preferably be able to provide pulses having fluences of the order of $100J/cm^2$ and peak power of the order of $1000W/cm^2$. A spot size of the order of 10mm is preferable, to reduce scattering losses.

Laser light sources that should be appropriate include a Nd~~(Yag)~~:YAG laser, a ruby laser, an alexandrite laser, diode lasers and others will be suitable. Incoherent light sources such as a xenon flashlamp should also be appropriate.

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A method for cutaneous resurfacing (skin rejuvenation) in accordance with the present invention includes use of an Er:YAG laser light, which has a most efficient wavelength of 2.94μm. Because the absorption depth of an Er:YAG laser in skin is very small (less than 20 microns), it may be difficult to ablate to a depth of the order of 100 microns or more (typical of the epidermis) with it. However, a deeper depth of peeling can be achieved by extending the pulse length of the laser. While this is hard to achieve using an Er:YAG laser due to the inherent short level lifetime, by providing a few pulses with a variable delay between the pulses this limitation may be overcome. Evaporated tissue layer thickness may be controlled by the number of pulses and variation of pulse parameters and delay between pulses.

The invention also relates to an apparatus using a flashlamp light source, or any other source with appropriate parameters, for smoothing wrinkles, without damaging the epidermis. Also, an Er:YAG laser is used for efficient skin rejuvenation by removal of the epidermis.

Generally, the device includes a flashlamp that can provide a pulsed light in the range of 600-1200nm for heating of collagen, a filter system that can cut off the radiation spectrum below approximately 600nm, a light guide that can provide an appropriate spot size and can provide fluences of the order of 100 J/cm^2, and an Er:YAG laser with pulse energy of the order of 1J, which can be operated in

multiple pulse mode with delays between pulses of less than 50msec for skin rejuvenation (by skin ablative peeling).

In one alternative a light source such as a Nd(Yag) laser or ruby laser with appropriate parameters could replace the flashlamp.

This apparatus is very useful for wrinkle removal and skin rejuvenation. A flashlamp light source, particularly when used with external cooling of skin surface, will generate a temperature distribution inside the skin which has a maximum at depth dependent on the light and cooling. Consequently, it is possible to heat collagen molecules without damaging the epidermis. The temperature distribution in the skin is responsive to the delay time between the cooling and application of light, selection of pulse parameters and the radiation spectrum. Accordingly, appropriate control of these parameters allows control of the temperature distribution. An Er:YAG laser operated in multiple pulse mode is very efficient for cutaneous resurfacing procedures and also enables control of depth of evaporation. Thus, the apparatus is safe with little risk of accidental injury to the operator and patient.

As stated above, wrinkles may be smoothed by shrinking collagen molecules using pulsed heating. The present invention method is realized by heating of tissue to depths of up to a few millimeters by light radiation in association with external cooling of skin outer surface to avoid overheating of epidermis. The epidermis may be cooled using many methods. One preferred method is the application of a previously cooled transparent matter like ice or cold gel on the skin which cools the skin before and during treatment. A temperature distribution inside the skin similar to one shown in Figure 1 is created a short time (of

the order of 1 second) after the application of the cooled material.

As may be seen, the distribution is such that the epidermis and the outer layer of the skin are colder than the more deeper part of the skin. However, the applied light heats up the superficial parts of the skin more than the inner parts, because of the attenuation of light energy fluence by depth, and due to higher absorption of light by the epidermis.

After heating a temperature distribution such as that shown in Figure 2 results. As may be seen, the deeper parts of the tissue are heated up to a temperature sufficient to cause collagen shrinking, but without damaging the outer parts of the skin (epidermis).

The temperature distribution generated prior to the application of light (Figure 1) is a function of the initial temperature of the cooling material and the delay time between the application of the cooling material and the application of light. By varying this time the depth of penetration of the "cool front" can be varied. When collagen that is deeper needs to be treated without influencing the superficial skin, a longer delay time between the application of the coolant and the light can be used. When the superficial collagen needs to be treated, a shorter delay time can be used.

In a typical treatment the doctor applies the cold gel to the skin before treatment and then applies the light source. In accordance with one embodiment of the invention, the treatment device indicates to the doctor when the light source needs to be applied after application of the cooling material, to achieve a desired temperature distribution. A microprocessor that controls the light generating device may

also generate a timing signal for the doctor to accomplish this aspect of the invention.

The applicants have determined that a light source having the following parameters is suitable for implementing the invention.

Light radiation should penetrate into a tissue at a millimeter depth. Examples of light sources which meet the parameter include flashlamp, diode laser, Nd:YAG ~~(Yag)~~ laser and ruby laser.

Optical power should be on the order of 100-1000 W/cm^2.

Fluence should be on the order of 30-150 J/cm^2.

Spot size should be on the order of a few millimeters to some centimeters, preferably variable over a range.

A detailed description of one preferred embodiment will be described with reference to Figure 3. As shown in Figure 3, a treatment device 300 includes a flashlamp 301 which can be operated in pulse mode, a reflector 302 which forms a light beam and conducts it to a light guide 305 through a filter system 303 and 304. Reflector 302 is located in a treatment head (or housing) 306.

Filter system 303 and 304 may include one or more filters which cut off the radiation spectrum at approximately 550(or 600)-800nm. Filter 303 provides reflection of the part of unused incident radiation and avoids overheating of absorbing filter 304. Absorbing filter cuts off radiation at approximately 550-800nm. Flexible light guide 305 can be interchanged with a rigid light guide made out of quartz or other types of high optical quality glass. Treatment head 305 is useful for treating large areas.

According to one embodiment, the light energy is applied to the skin using a train of pulses. One advantage of applying a train of pulses is that the epidermis cools relative to the layer of collagen that is heated in the treatment. Preferably, the apparatus produces a train of pulses with variable delays between pulses in the range of 10's to 100's of milliseconds.

The total number of pulses per pulse train can also be varied. More specifically, for a patient with higher skin absorption due to heavier skin pigmentation a larger number of pulses per train is preferably used.

Similarly, the pulse duration of each pulse in the train can also be varied in order to enable cooling of the epidermis without cooling the collagen. In any event, the total dose to the treated area is the product of the number of pulses and the fluence per pulse. The pulse duration, and train length are controlled in one embodiment by a microprocessor 309. As shown on Figure 3, microprocessor 309 provides control signals to pulse forming network 310. Pulse forming network 310 (generally of the type described in commonly owned U.S. Patent No. 5,405,368, which is incorporated herein by reference) provides pulse to flashlamp 301.

The radiation spectrum can be controlled by filter system 303 and 304. Additionally (or alternatively), the spectrum of radiation can be controlled by varying the current density through the flashlamp. If deeper heating is required a longer wavelength radiation is used. Pulse duration may be varied in the range of a few milliseconds to a few ten's of milliseconds.

Other embodiments of the present invention include the use of lasers (those having proper penetration), which

can also be very effective to smooth wrinkles. For example, a flashlamp pumped Nd:YAG~~(Yag)~~ laser operating at 1.06μm can provide deep penetration and thus be effective. The laser may be operated in the pulsed train mode, preferably by pulsing the flashlamps that are used to pump the laser. Similarly, a ruby laser may be used. However, the pulse duration cannot be made too long due to the limited value of the lifetime of the lasing level of these lasers. In the laser embodiment, there is no need for filters since the light is monochromatic. Also this embodiment does not require the use of a rigid light guide since flexible light guides are readily available for laser applications and a low divergence laser beam can be easily focused into a small diameter optical fiber. The use of multiple pulses may be particularly useful to overcome the limited lasing level in the laser embodiment of the invention.

The cutaneous resurfacing method in accordance with the present invention includes an Er:YAG laser light, whose radiation has an absorption depth of much less than that of CO_2 laser radiation, of the order of 50 micron is used. Despite the relatively low absorption depth, an appropriate peeling depth is reached by providing multiple pulses. The thickness of the layer of evaporated tissue may be controlled by the number of pulses, the delay between pulses and varying pulse parameters.

Er:YAG lasers produce radiation of 2.94μm, with an energy per pulse of up to 1J. Absorption depth of the radiation is typically about 10μm. Thus, to evaporate an epidermis, a train of pulses should be used. Typical delay between the laser pulses should be in the range of 0.5-10msec. The time should preferably be shorter than, or on the order of, the epidermis thermal relaxation time.

Thus, it should be apparent that there has been provided in accordance with the present invention a treatment device that includes a flashlamp or a near infrared pulsed laser in another embodiment, an Er:YAG laser and a coupler that fully satisfy the objectives and advantages set forth above. Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.